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An Account of EXPERIMENTS *made to determine the* TEMPERATURE *of the* EARTH's SURFACE *in the Kingdom of Ireland in the Year* 1788. *By the Reverend* WILLIAM HAMILTON, *F.T.C.D. and M.R.I.A.*

Read Dec. 6, 1788.

I T is a queſtion as ancient as the days of the Scythians and Egyptians, whether the temperature of the earth be a permanent or variable quantity*. Unfortunately theſe early nations, deſtitute of proper inſtruments for aſcertaining the temperature of their reſpective kingdoms, have not given us any aſſiſtance in reſolving this curious and intereſting problem, which has been handed down to poſterity with no other attendants than vague and illuſive ſpeculations.

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[*] See Juſtin, l. 2, c. 1.

In the preſent age this enquiry has been revived, and purſued with all the fruitleſs enthuſiaſm of antiquity, affording the cleareſt proof that the ſpeculative reaſonings of mankind for three thouſand years, are unequal to the taſk of deciding a queſtion which attentive experiments would probably have reſolved in a much ſhorter period of time.

The Count de Buffon has indeed ventured to aſſert that the temperature of the earth has been for many ages a decreaſing quantity; but a ſlight view of the ſteps by which that gentleman conducted himſelf to this haſty opinion will eaſily ſatisfy one that neither his experiments, nor his reaſonings, are adequate to the concluſions which he has deduced from them; ſince it is obvious that any proofs derived from the cooling of heated bodies on the earth's ſurface, in a medium of known denſity, and a determinate capacity for receiving heat, become extremely deceitful when applied to the diminution of temperature which may take place in a body ſituated, as the earth is, either in vacuo, or in a medium whoſe denſity and capacity for heat is altogether indefinite.

From obſervations on the warmth of the earth itſelf, on the heat of various ſprings of water, and on the eruptions of volcanoes, many philoſophers have been led to conclude the exiſtence of a central fire, by which theſe phænomena might be explained; and, were this concluſion well founded, it might ſeem that the temperature of the earth's ſurface ought to be an encreaſing quantity: but it is certain that the accumulation of heat communicated to the ſurface of the earth in ſummer, will

will ſufficiently account for its relative heat in winter; while the decompoſition of various minerals at conſiderable depths, will afford a reaſonable explanation of the other phænomena: ſo that theſe obſervations do not at all neceſſarily lead us to believe in the exiſtence of a central fire, and experiments made at conſiderable depths within the earth, evidently tend to diſcountenance it.

WHATEVER be the truth, whether the general temperature of the earth be an encreaſing, a permanent, or decreaſing quantity, it is likely that poſterity will be able to form a probable concluſion on the ſubject, from a compariſon of future experiments with thoſe of the preſent age. But there is another queſtion of ſufficient importance to us, which may poſſibly admit of an earlier anſwer; Whether the temperature of particular countries be ſubject to any conſiderable variations, which, in the courſe of ages may be capable of influencing their vegetable and animal productions, and the affections of their atmoſphere.

WE have experience enough, even in our temperate iſland, to ſatisfy us, that the cauſes of heat and cold are not abſolutely uniform; ſince it never happens that two ſucceſſive years are alike throughout, in the temperature of their ſeveral months: Inſtances have even frequently occurred, wherein the temperature of the month of January has rivalled the genial warmth of May.

WE often behold a ſucceſſion of years wherein winter ſeems to have entirely loſt its uſual horror, while the arbutus, the laurel, the myrtle, and the rareſt ſpecies of evergreens, ſpring up with the vigour of indigenous plants, almoſt emulating in ſize the trees of the foreſt. Again, periods occur which ſenſibly remind us of our vicinity to the polar ice, periods in which the luxuriant foliage of our more tender plants is entirely withered and deſtroyed, and when even the mountain pine can ſcarcely maintain its hardy ſhoots.

HENCE it is plain, that the ſources of heat and cold in our climate are variable in different years; and it is a problem, curious and intereſting in its own nature, to determine what may be the effect on the general temperature of the kingdom, whether it be an encreaſing or decreaſing quantity? whether it be ſubject to periods of encreaſe and of diminution? and whether theſe periods, and the rate of their variations, be uniform or irregular?

FOR this purpoſe I have endeavoured, by ſuch means as were in my power, to aſcertain the temperature of the ſoil of Ireland, from its ſouthern to its northern coaſt, in the year 1788 and part of 1787, the reſults of which I here offer to the academy.

BUT firſt, it will be neceſſary to ſtate the methods which have been uſed to procure theſe reſults, that ſhould it be thought worth while to repeat the experiments at any future time, they may be made under circumſtances as nearly ſimilar as poſſible to the original ones, which alone can give us reaſonable hope of a right concluſion, where the difference of temperature, even in a great number of years, will probably be exceedingly ſmall.

Experience ſhews us, that the ſurface of the earth encreaſes in its heat during the ſummer, and decreaſes during winter: Of this our ſenſes give us ſufficient notice; and were the greateſt heat in ſummer, and the leaſt in winter obſerved, the mean of theſe would give a reſult ſomewhat approaching to the mean temperature of the ſurface of the earth during that year.

But the quantity thus reſulting, would ſeldom correſpond accurately with the truth; becauſe, the ſurface of the earth being expoſed to the immediate effects of the atmoſphere, to rains and wind, to clouds and ſunſhine, it is evidently ſubject to rapid diurnal variations of heat, which render it an unfit ſtandard from whence to derive the mean temperature of the year, by any induction from a ſmall number of experiments.

At the depth of thirty, forty, or fifty feet beneath the ſurface, theſe diurnal variations ſeem to loſe their influence; while a ſlow and gradual change of temperature takes place, which is not ſenſible except after intervals of many days. At ſuch depths the earth, in our climate, is uſually found at its loweſt degree of cold about one month after the vernal equinox; from that time, it ſlowly and progreſſively acquires heat, until about a month after the autumnal equinox, at which period it commonly poſſeſſes its maximum of temperature. After this, gradually parting with heat during the winter, it becomes again cooled to its extreme degree ſoon after the commencement of the following ſpring*; and thus ſuffers as it were an annual tide of temperature, higheſt before the beginning of winter, and loweſt at the commencement of ſpring.

HENCE, by proper obſervations, we have an opportunity of diſcovering the proportional increments or decrements of heat communicated to the maſs of earth at certain depths, during the *months* of any one year, for the purpoſe of comparing them with the reſpective increments and decrements of the correſpondent *months* of any other year: and alſo, from an obſervation of the maximum and minimum of heat in different *years*, we are enabled to derive the mean temperature of the outward maſs of earth in ſuch *years*, and thus to make a compariſon between the annual temperatures themſelves at different periods.

AT the depth of eighty feet beneath its ſurface (in covered ſituations) the earth is not at all affected, even in many months, by the ſuperficial alterations of heat; and the moſt ſenſible thermometer is ſcarcely competent to diſcover any change throughout the year. Here then the diurnal and even monthly variations of temperature loſe their influence, and the annual changes alone become perceivable.

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* The times of the year at which the maximum and minimum of temperature happen, are different at different depths, earlier at a leſs depth, and later at a greater. Heavy rains about the equinoxes ſeem to expedite the effect: Thus, in the wet autumn of 1787 the temperature began to decreaſe in the beginning of October, in ſituations, where, in the dry ſeaſon of 1788 it did not take place till the month of December. Count Caſſini informed me that the ſame obſervation was uſually made in the cave of the Obſervatory at Paris.

Hence it appears that the *diurnal variations* of temperature manifeſt their effects at the ſurface of the earth, where they are beſt to be obſerved. That the *monthly changes* alone, are perceivable at depths of thirty or forty feet; in which ſituations we have the power of comparing correſpondent increments or decrements of heat in different months with each other, or even the medium temperature of different years. It further appears that at the depth of eighty feet and upward, even the monthly variations loſe their influence, while the *annual changes* alone, become perceivable: At ſuch depths, therefore, the acceſs or diminution of heat, in ſucceſſive periods of years, may moſt accurately be obſerved; and attentive experiments, thus made in different climates, may not only throw light on the variations of temperature in ſuch particular climates, but may at length tend to ſolve the problem concerning the general temperature of the earth itſelf, which has in vain been agitated for ſo many ages.

The beſt method of determining the degree of heat, at conſiderable depths, might naturally ſeem to offer itſelf in mines; but experience proves theſe to be extremely fallacious, ſince the decompoſition of mineral ſubſtances often produces caſual varieties which may very much miſlead us. Thus, to give a ſingle inſtance; the ſtreams which run from three of the principal levels of the Ballycaſtle coal pits give a mean degree of heat equal to 51° of of Farenheit's ſcale, which is three degrees above the general temperature of the northern coaſt, and equal to that of Cork, though ſituated above three degrees of latitude farther to the ſouth: while the water, iſſuing from a new level opened in the year 1787, produces a mean temperature only equal to 46°, which is two degrees below that of the northern coaſt itſelf; ſo that in theſe pits there is a variation of five degrees of temperature at the leaſt*.

For this reaſon experiments are rather to be derived from covered wells of pure water; and it matters little whether ſuch wells be ſupplied by ſprings, or by a ſlow filtration, ſince the water, long reſting at the bottom of each well, will always give the temperature of the earth at that depth; and conſiſtence, or inconſiſtence, in experiments made at different places not very diſtant from each other, will always enable an attentive obſerver to conjecture concerning the fairneſs of the trial.

The firſt table, which is annexed to this paper, marks the temperature of the coaſt of Ireland in different degrees of latitude. By this it will appear that there is, at preſent, a difference of $3\frac{2}{10}$ degrees of heat, (as marked by Farenheit's ſcale) between our northern and ſouthern coaſt, through a difference of latitude equal to 3° 18′; ſo that the variation of heat, in our iſland, is

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* This latter level is opened on a little bay called Port na Graigh, (the Mares Port); and I was conducted to it in conſequence of the complaints of the workmen, who ſuffered very much from the intenſity of the cold. It was then the month of Auguſt, 1787, and yet the temperature of the pit was ſo low as 47, 5.

at a rate nearly equal to one degree of temperature for each degree of latitude.

The ſecond table marks the temperature of places in the kingdom, which are not ſituated on the ſea coaſt. From this we have ſome data for inferring the effects which ariſe in conſequence of diſtance from the ſea, and elevation. Thus it will be found, that the country adjoining to Tullamore in the King's county, near the *centre* of the kingdom, about *fifty miles* diſtant from the Iriſh channel on one ſide, and as much from the weſtern ocean at the bay of Galway on the other ſide of Ireland, *gradually elevated* to the height of *two hundred and ſix feet* above the level of the ſea *, and not very far beneath the higheſt point of the *general* ſurface of our iſland †, poſſeſſes a mean temperature nearly correſponding to a ſituation on the coaſt two degrees more northerly.

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* The elevation of the country at Tullamore is thus proved:

	Feet.
Elevation of the Canal baſon at James's-ſtreet; in Dublin, above the mean height of the tide at the Marine ſchool on the river Liffey, *by obſervations made for the Canal Company*, - - - -	67½
Elevation of the *ſummit level* of the Canal above the Baſon in James's-ſtreet. *See Brownrigg's Survey*, - - - -	202½
Total elevation of ſummit level, - -	270
Depreſſion of Tullamore, below the ſummit level. *See ſtatement laid before Parliament*, - - - -	64
Hence elevation of Tullamore above the mean height of the tide in the river Liffey - - - - - -	206

† It may ſeem ſtrange that a tract of country full of moraſſes, ſhould nevertheleſs, be marked as almoſt the higheſt part of the *general* ſurface of the kingdom; yet there

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In the third table is written the temperature of the ſoil, as obſerved in conſiderable towns; from whence it may be inferred, that there is an artificial encreaſe of heat uſually communicated to the ſurface of the earth in ſuch places, varying conſiderably from the mean temperature of the contiguous country. This is to be eſteemed the reſult of the warmth communicated directly from the quantity of fuel burnt in ſuch towns, and from the heated air and ſmoke which, more or leſs,

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is great reaſon to believe that the Bog of Allen, wherein is placed the ſummit level of the Grand Canal, is in reality elevated above a very large portion of the ſurface of Ireland; which may be inferred from the following circumſtances:

From the Bog of Allen the River Barrow derives the greater part of its waters; and at Monaſterevan, (from whence it has yet a courſe of ſixty-eight Iriſh miles to traverſe before it reaches the ſouthern ſea on the coaſt of Waterford;) its depreſſion is eighty feet below the ſummit level of the Grand Canal. *See Brownrigg's ſurvey.*

From the ſame ſource riſes the River Boyne, which, after a north-eaſt courſe of forty miles, diſcharges itſelf into St. George's Channel, on the eaſtern coaſt of the kingdom *(ſee map of Ireland)*; and the elevation of the Bog of Allen is proved to be two hundred and ſeventy feet above the eaſtern coaſt at Dublin. *See preceding note.*

Weſterly, the deſcent is every where toward the Shannon, *(ſee ſurveys before parliament)* even to the ſource of its waters, *(compare Cowen's ſurvey of the Shannon with Brownrigg's ſurvey of the Canal)* ſo that this ſpacious river, which, riſing from the borders of the northern province of Ulſter, waſhes the ſhores of the three remaining provinces of Ireland through a courſe of one hundred and eighteen miles, *(ſee Cowen's ſurvey)* is every where conſiderably depreſſed beneath the Bog of Allen.

Hence it appears, that in a ſoutherly direction as far as Waterford; eaſterly, to Dublin and Drogheda; northerly, as far as Lough Allen; and weſterly, to the ocean at the mouth of the River Shannon; the deſcent of the kingdom is every where from this extenſive moraſs.

reſts over the ſurface. It is here noticed, to prevent errors in experiments derived from ſuch ſituations; and to ſhew, in general, the unfitneſs of great cities for determining, with accuracy, the true temperature of the year; in which places, nevertheleſs, experiments of this kind have uſually been made, without any correction for ſuch irregularities.

THE local diſpoſition of our iſland, conſiderably advanced into the Weſtern Ocean beyond the other ſhores of Europe, and removed from the immediate influence of any great tract of mountainous country, renders it peculiarly fitted for a ſtandard ſituation, to which the obſervations of other countries may be conveniently referred, for which reaſon theſe experiments have been made with attention.

THE thermometers uſed were graduated from a common ſtandard; and that ſtandard itſelf carefully made, and compared with many of the beſt thermometers of different countries; yet ſtill I would adviſe that the reſults be not too implicitly confided in, until ſupported by ſucceeding experiments.

TABLE I.

Mean Temperature of the Sea-Coaſt *of Ireland, obſerved in different Latitudes.*

Lat. 55° 12′	Medium temperature of the northern coaſt of Ireland, near the town of Ballycaſtle, obſerved in the year 1788, by means of copious ſprings flowing from a limeſtone ſoil* - -	48,
Lat. 54° 48′	Medium temperature of the iſland of Eniſcoo, one of the Roſſes iſlands, on the weſtern coaſt of Ireland, obſerved by means of a covered well in a granite rock; the maximum of temperature taken in 1787, the minimum† in 1788 -	48, 6
Lat. 53° 20′	Medium temperature of the eaſtern coaſt of Ireland, near Dublin, obſerved by means of deep covered wells in ſoils of clay, gravel and limeſtone, 1788 - - -	49, 4
Lat. 51° 54′	Medium temperature of the ſouth coaſt of Ireland, near the city of Cork, obſerved by means of deep covered wells in limeſtone and other ſoils‡, 1788 - - -	51, 2

[*] Obſerved by Mr. Edmond Mc. Gildowny.

[†] Minimum obſerved by Robert Corbet, Eſq;

[‡] Obſerved by J. Longfield, Eſq; M. D.

TABLE

TABLE II.

Mean Temperatures of Places diſtant *from the Sea, and* elevated *above its Surface.*

Lat. 55°	Medium temperature* in the neighbourhood of Londonderry, diſtant twenty *Iriſh*† miles from the northern ſea, and at a ſuppoſed elevation of one hundred feet above it (1788)	46,9
Lat. 54° 20′	Medium temperature‡ in the neighbourhood of Armagh, diſtant twenty-five miles from the Iriſh Channel, and elevated about fifty-eight feet above the coaſt §, by means of a well ſixty feet deep ſunk to the bottom of a gravelly hill, (1788)	47,5

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* Obſerved by William Patterſon, Eſq; M. D.

† 54½ Iriſh miles are almoſt equal to a degree of the meridian, that is to 60 geographical miles, or to 69½ Engliſh miles.

‡ Obſerved by the Rev. Dean Hamilton.

§ This elevation is preſumed from the following circumſtances:

	Feet.
Elevation of Lough Neagh above the ſea, from obſervations (*ſee Whitworth's Reports*) that have lately been found extremely correct	38
From Lough Neagh to Blackwater town, through a diſtance of ſeven or eight miles, the river Blackwater is navigable, and extremely ſtill, ſo that its fall cannot exceed	10
From Blackwater town to the valley of Armagh is a direct diſtance of about four miles; for that ſpace the elevation here marked is only the reſult of conjecture	10
Total	58

Lat. 53° 12′	Medium temperature derived from the maximum of 1787, and minimum * of 1788, in the neighbourhood of Tullamore (in the King's county) near the *center* of the kingdom, *diſtant* fifty miles from both the ſeas †, *elevated* two hundred and ſix feet above the coaſt ‡, in a *level country*, which may be counted the higheſt ground of the general ſurface of Ireland § -	48,

T A B L E III.

Mean Temperature in Cities.

MEDIUM temperature in different parts of the city of Londonderry by maximum of 1787, and minimum of 1788, various from - -	47, 6 to 49
MEDIUM temperature in different parts of the city of Dublin in 1788 - -	50 to 52
MEDIUM temperature in different parts of the city of Cork in the year 1788 - -	52, 5 to 53, 5

* Minimum obſerved by the Rev. Peter Turpin.

† See map of Ireland.

‡ For proof of this, ſee note in page 151.

§ See the ſecond note in page 151.